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Evaluation of Chicken Eggshell Biocoagulant Application in Domestic Wastewater Treatment

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Abstract:

The increasing population in Bogor City, especially in the Tanah Baru area, leads to an increase in the volume of domestic wastewater and municipal waste such as chicken eggshells. Chicken eggshells have the potential to be used as an environmentally friendly biocoagulant to reduce pollutant load, but their effectiveness on domestic wastewater still needs to be studied. This study aims to analyze the effect of adding chicken eggshell biocoagulant on changes in pH, TDS, and conductivity parameters of domestic wastewater and compare it with the conventional coagulant polyaluminum chloride (PAC). The methods used include preparing chicken eggshell powder through washing, drying, grinding, sieving, and chemical activation, then applying it to wastewater samples at a dosage of 50 g/500 mL and comparing it with PAC at a dosage of 1 mL/500 mL using the jar test. The results show that adding chicken eggshell biocoagulant did not significantly reduce pollutant load, even causing an increase in TDS and conductivity, while PAC was able to improve wastewater quality with much lower increases in TDS and conductivity, and the pH remained within the quality standard range. These findings indicate that chemically, chicken eggshells are more suitable for use as an adsorbent or support material in coagulation systems than as the primary coagulant in domestic wastewater treatment.

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Introduction

The increasing population in Bogor City, especially in the Tanah Baru area, has a direct impact on the increase in municipal waste volume, including chicken eggshell waste

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generated from high egg consumption. Data from 2024 shows an increase in the population of North Bogor District (which includes Tanah Baru) to approximately 1,207 people (BPS Kota Bogor, 2025). This condition increases the potential for environmental problems, especially regarding the increasingly complex management of municipal waste and domestic wastewater. Population growth also contributes to water pollution and the decline of ecosystem function, particularly in areas experiencing massive development without adequate environmental management (Pratama et al., 2024). Chicken eggshell waste, which has often been discarded without a second thought, can be an alternative solution for domestic wastewater treatment. The use of chicken eggshells as a biocoagulant not only helps reduce the volume of solid waste but also contributes to the efficiency of wastewater treatment in a natural and environmentally friendly way (Cahyadinata, 2023). Chicken eggshells are constituted by a majority of calcium carbonate (94%), calcium phosphate (1%), and magnesium carbonate along with some organic components and water (Nguyen, 2022). Generally, plant seed-derived or chicken eggshell-derived coagulants exhibit a cationic nature, enabling them to counteract anionic particles or colloids present in raw water that carry a negative charge (Villareal-Lucio et al., 2018). This interaction facilitates the optimal formation of flocs. Notably, in the case of the biocoagulant derived from chicken eggshells, it exhibited impressive efficacy in treating liquid waste from the pharmaceutical industry, achieving an 81.18% reduction in turbidity and a 24.3% reduction in TDS (total dissolved solids) (Hanifah et al., 2020), a TDS removal efficiency of 42%, and a turbidity removal efficiency of 94.26% (H. Rifqyawarman et al., 2024). Moreover, the application of chicken eggshells as a biocoagulant offers significant health benefits by minimizing adverse effects associated with chemical coagulants, such as neurotoxicity, carcinogenicity, genotoxicity, and additional carcinogenic risks, thereby presenting a safer alternative for wastewater treatment processes (A. Gebrekidan et *al.*, 2013). By applying the biocoagulant from chicken eggshells in the Tanah Baru wastewater treatment plant, the wastewater treatment process can be more effective, while also supporting sustainable waste management programs amidst the increasing population and household activities in the area. However, the study results indicate that the performance of chicken eggshell biocoagulants is not always consistent and in some conditions only provides limited reduction in water quality parameters compared to conventional inorganic coagulants. The insignificance of this pollutant load reduction is important to study further, both from the perspective of changes in the physical-chemical parameters of the wastewater and its relationship to the chemical characteristics of the eggshell itself.

Methods

This research method involves the main materials of chicken eggshells, distilled water, 3% HCl, 96% ethanol, and domestic wastewater from the Tanah Baru Wastewater Treatment Plant. The stages begin with initial testing of wastewater parameters such as pH, TDS, and conductivity to determine the quality before treatment. Next, the chicken eggshells were washed using distilled water, dried in an oven at 105°C for 2 hours, ground into a powder using a grinder, then sieved using a 100-mesh sieve, activated with 3% HCl, and filtered. The activated powder was soaked in 96% ethanol and filtered again. The final biocoagulant was then added to the wastewater samples with a dosage variation of 50 g biocoagulant per 500 mL wastewater. PAC at a dosage of 1 mL per 500 mL wastewater was used as a comparison. Both variations were then tested using the jar test. After the coagulation process is complete, final testing is conducted to assess changes in pH, TDS,

and conductivity values after treatment using chicken eggshell biocoagulant.

Results

To determine the initial condition of the wastewater to be tested, an analysis of several basic water quality parameters was conducted. This testing aims to provide a general overview of the wastewater characteristics before treatment with biocoagulants. The parameters tested include pH, total dissolved solids (TDS), and conductivity. The results of the testing can be seen in **Table 1.**

Table 1. Wastewater testing results before treatment

No	Parameter	Result	Unit
1	pH	7,07	-
2	TDS	121	Ppm
3	Conductivity	241	µs/cm

Source : Research findings, 2025.

After initial measurements were taken, the treatment process using a biocoagulant was then applied to the wastewater samples. This step was performed to assess the wastewater's response to the coagulant material used. The retesting was conducted with the same parameters to obtain comparative data. The test results after the addition of the biocoagulant are presented in **Table 2.**

Table 2. Wastewater testing results after treatment

No	Variation	Parameter	Result	Unit
1	50 g Eggshell	pH	7,08	-
		TDS	308	ppm
		Conductivity	622	µs/cm
2	PAC	pH	7,22	-
		TDS	143	ppm
		Conductivity	287	µs/cm

Source : Research findings, 2025.

Based on **Table 1** and **Table 2**, the TDS value of the wastewater increased from 121 ppm before the addition of the biocoagulant to 308 ppm after treatment, while the conductivity rose from 241 µS/cm to 622 µS/cm. The increase in both indicates that treatment with chicken eggshell powder actually adds to the amount of dissolved substances and ions in the water, such as calcium and magnesium ions released from the shells. This increase in TDS and conductivity suggests that the coagulation process is not effective in binding and precipitating dissolved components and may even potentially increase the load of dissolved salts in the wastewater.

The addition of PAC coagulant to domestic wastewater showed better quality improvement compared to chicken eggshell biocoagulant, as reflected by the pH value increasing from 7.07 to 7.22, thus remaining within the neutral range suitable for domestic wastewater quality standards (pH 6–9). Additionally, the TDS value only increased moderately from 121 ppm to 143 ppm, and conductivity from 241 µS/cm to 287 µS/cm, which is significantly lower than the increase observed in the chicken eggshell treatment. This indicates that PAC is more effective at coagulating and settling colloids without

significantly increasing the dissolved solids load in the wastewater.

Compared to the Minister of Environment and Forestry Regulation Number 68 of 2016, domestic wastewater has not yet established quality criteria for TDS and conductivity, so the results do not exceed the limits set for these two parameters. However, in general, water quality, increased TDS, and conductivity indicate a decline in quality due to an increase in dissolved particles and electrical charge in the water, which can disrupt aquatic life and lead to increased water usage. This situation is very important to monitor because the goal of wastewater treatment should be to reduce, not increase, the concentration of dissolved substances.

According to Firnanelty (2025), the composition of a chicken eggshell is primarily calcium carbonate ($CaCO_3$), making up about 94–98%, along with magnesium carbonate, calcium phosphate, and organic fractions such as proteins and polysaccharides in the inner membrane. The Fourier Transform Infrared (FTIR) analysis also confirms dual signs of the presence of $CaCO_3$, which is marked by the occurrence of OH, CO, CH, and CaO functional groups (Ulfa et al., 2019). But the dominant inorganic components are slightly soluble but can still release calcium ions and carbonate/bicarbonate anions into the water, while the organic fraction is relatively small. This structure makes chicken eggshells more suitable to act as an adsorbent or pH buffering material rather than as a highly charged coagulant (Aziz, 2022).

If the particle size of chicken eggshells is too large or the dosage is too high, the flocculation process becomes inefficient, resulting in unstable flocs that may even increase the turbidity of wastewater. Additionally, the high content of calcium carbonate can elevate the pH, potentially causing precipitation of metal ions and the formation of fine particles that are not effectively coagulated. These conditions can make the wastewater more turbid than before treatment. Also, a previous study mentioned that the smaller the size of the biocoagulant, the greater the reduction of TDS and turbidity (H. Rifqyawarman et al., 2024).

Effective coagulants typically contain a significant positive charge, such as aluminum or iron salts, or long polymer chains with multiple active groups, which allows them to neutralize the charge of colloidal particles and create large flocs that settle easily (Marwanto and Mulyati, 2022). Most of the $CaCO_3$ in chicken eggshells is not reactive enough to create a significant charge neutralization effect, and there are not enough membrane proteins with amine and carboxylate groups to produce significant intercolloidal attraction. As a result, floc formation is limited, and turbidity, total suspended solids (TSS), and dissolved contaminants can only be reduced to a certain extent.

Conclusion

Thus, the combination of increased TDS and conductivity, the lack of specific quality standards but the presence of signs of water quality deterioration, and the chemical nature of chicken eggshells, which are more passive minerals than active coagulants, explain why chicken eggshell bio-coagulants were ineffective under these experimental conditions. Further adjustments are needed to improve performance, such as stronger chemical activation, combination with other coagulants, or primary use as an adsorbent so that wastewater treatment can be carried out without increasing the load of dissolved substances.

Suggestion

Some suggestions that align with this conclusion can be formulated as follows.

1. Further research is suggested to perform stronger chemical modifications or activations (e.g., calcination or different acid/base activations) to increase the surface reactivity of chicken eggshells so they function more effectively as a coagulant, rather than just a passive mineral.
2. It is recommended to study the use of chicken eggshells in hybrid form, for example, combined with conventional chemical coagulants (PAC or alum) or other biocoagulants, so that the role of eggshells is more as an adjunct that reduces the dosage requirement of the main coagulant.
3. Considering its more suitable nature as an absorbent, the utilization of chicken eggshells should also be researched as a biosorbent in the post-coagulation stage to absorb residual heavy metals or specific compounds, while monitoring to ensure there is no increase in TDS and conductivity.

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